

# ORGANIC AND TRACE METAL LEVELS IN OCEAN QUAHOG, *ARCTICA ISLANDICA* LINNÉ, FROM THE NORTHWESTERN ATLANTIC

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## ABSTRACT

Chemical contamination of biological resources is an important problem for resource managers. This study reports on body burden levels of several contaminants of concern: polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAH) of both petroleum and combustion sources, total petroleum hydrocarbons, and seven trace metals (Ag, Cd, Cr, Cu, Ni, Pb, and Zn) in a resource species, the ocean quahog, collected between Virginia and Nova Scotia. Organic and trace metal contaminants were detected, at low levels, in all samples examined, with highest levels being generally found in samples from the inner New York Bight and Rhode Island Sound. The highest PCB and PAH values were 27 and 55 ppb, respectively; Ag, Cd, and Cr values were generally <5 µg/g dry weight; Cu, Ni, and Pb generally <15 µg/g dry weight with a few exceptions; and Zn ranged from 50 to 153 µg/g dry weight.

The ocean quahog, *Arctica islandica* Linné, is a large, bivalve mollusc found on both sides of the North Atlantic. In the northwestern Atlantic, it occurs from just north of Cape Hatteras, NC, to Newfoundland, Nova Scotia, being most abundant on the middle to outer continental shelf at depths between about 30 and 150 m (Merrill et al. 1969). The species is edible and some commercial harvesting has occurred since 1943 in the Rhode Island area; however, intensive fishing for this species did not begin until the 1970s when surf clam, *Spisula solidissima* (Dillwyn), stocks, an inshore species, were drastically reduced by overfishing (Ropes 1979).

*Arctica islandica* generally inhabit silty sand sediments of the middle to outer continental shelf that are less influenced by waves and strong currents than shallower areas. Areas of silty sand are thought to be at least partially depositional in nature, i.e., fine organic-rich particles tend to accumulate. It is generally agreed that many chemical pollutants, introduced to the marine environment via impacted estuaries and coastal areas, ocean dumping, and atmospheric sources, often are bound to and associated with fine organic and inorganic particle aggregates, both in the water column and at the sediment surface. These aggregates ultimately can accumulate in these natural depositional areas as the results of some recent studies show that contaminants ap-

parently are accumulating in silty areas relatively remote from most possible sources, e.g., organic contaminants found south of Cape Cod, MA, in the middle to outer continental shelf (Boehm 1983a). Some authors have also reported a trend of increasing sediment trace metal levels with depth on the Middle Atlantic shelf (Harris et al. 1977), but the specific sources of these contaminants are still unknown.

Because *A. islandica* is a common, sedentary, long-lived (Thompson et al. 1980) inhabitant of these silty sands that frequently contain higher levels of contaminants than coarser sands, the species may be particularly susceptible to contamination. Wenzloff et al. (1979) reported "greater average concentration of silver, arsenic, cadmium, copper, and zinc . . . in ocean quahogs than in surf clams" for the Middle Atlantic. Surf clams are generally found in shallower, medium sand areas. Thus, *A. islandica* may be a good offshore "indicator" species to monitor for trends in marine chemical pollution. Although some studies on contaminant body burdens of *A. islandica* have been reported (ERCO 1978<sup>3</sup>; Sick 1978, 1981; Wenzloff et al. 1979; Reynolds 1979; Payne et al. 1982), these studies have been limited generally to a particular restricted area, have not examined both types of contaminants or only a few components of each contaminant class, or have examined only certain tissues, not whole body levels.

The present study provides body burden data over

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<sup>3</sup>ERCO (Energy Resources Company). 1978. New England OCS Environmental Benchmark. Draft Final Rep., Vol. II, to U.S. Dep. Inter., Bur. Land Manage., Miner. Manage. Serv., 628 p.

a wide range of this species' occurrence in the northwestern Atlantic and includes information on organic, i.e., polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAH) from combustion and petroleum sources, and bulk levels of the petroleum hydrocarbon (PHC) class, and seven trace metal contaminants. The study includes the first known set of PCB data for this species.

## MATERIALS AND METHODS

Ocean quahog samples were obtained at random stations from wide areas on the continental shelf of the northwestern Atlantic (Fig. 1). These were collected from annual, summer hydraulic dredge shellfish surveys of NOAA's Northeast Fisheries Center from 1981 and 1982. At most stations, 10-12 medium-sized clams were selected, as available. Half of the collection was prepared for organic analysis by wrapping them in aluminum foil that had been prewashed with spectral grade acetone followed by dichloromethane; the remaining half for trace metals were placed in polyethylene plastic bags. All were quickly frozen at  $-20^{\circ}\text{C}$ . In certain areas where there were not sufficient samples at a particular station to provide material for both organics and trace metal analyses, samples were collected at a nearby station, with similar environmental characteristics, to complete the collection for the area. These paired station samples were not intermixed.

### Chemical Analysis - Organics

In the laboratory, the thawed whole meats of each of the five or six individual clams in each station sample were removed from the shells, pooled, and homogenized in a high-speed blender. A 100 g (wet weight) aliquot was removed from the homogenate and processed according to the extraction, fractionation, and analytical methodology described by Warner (1976), as modified by Boehm et al. (1982). After aqueous caustic (0.5N KOH) digestion of the tissue for 12 h, the digestate was back-extracted three times with hexane. The hexane extract was concentrated by rotary evaporation, then fractionated on a 5% deactivated alumina/activated silica gel column. The first eluting fraction from the alumina/silica column ( $f_1$ ) contained the saturated PHC; the second fraction ( $f_2$ ) contained the PCB and PAH. Quantitation procedures closely followed those by Boehm (1983b). PHC factors were quantified using the internal standard method whereby all peaks are quantified relative to androstane in the  $f_1$  fraction and 0-terphenyl in the  $f_2$  fraction.

PCBs were quantified relative to the internal standard tetrazene (2, 3, 5, 6 tetrachloronitrobenzene). The average relative response factors of two or three isomers in each of the di-, tri-, tetra-, penta-, hexa-, hepta- and octachlorobiphenyls groups were applied to the sum of the peaks in each grouping. Thus, PCBs were quantified by isomer group rather than according to the Aroclor<sup>4</sup>-type quantification (Duinker et al. 1980, 1983; Boehm 1983b). PHCs were determined by the total of  $f_1$  and  $f_2$  fractions, as analyzed by high resolution (fused silica capillary) gas chromatography with flame ionization detection ( $\text{GC}^2/\text{FID}$ ). A Hewlett Packard model 5840A gas chromatograph was used for all  $\text{GC}^2$  determinations. A 30 m fused silica SE-30 (0.25 mm i.d.; J and W Scientific) column was used to analyze the saturated hydrocarbon ( $f_1$ ) fraction. A 30 m SE-52 fused silica column was used to analyze the aromatic/olefinic ( $f_2$ ) fraction by  $\text{GC}^2/\text{FID}$  and the same fraction by gas chromatograph/mass spectrometer ( $\text{GC}/\text{MS}$ ) (see below). The  $f_2$  fractions were analyzed by  $\text{GC}^2/\text{ECD}$  (electron capture detection) to obtain the PCB concentrations. PCBs were analyzed on a 30 m SE-52 fused silica column. The  $f_2$  fraction was also analyzed by a Finnegan MAT model 4530 computer-assisted  $\text{GC}/\text{MS}$  system for PAH determinations.  $\text{GC}/\text{MS}$  conditions were as follows: ionization voltage, 70 eV; electron multiplier voltage 2,000 volts; scan conditions 45-450 amu at 400 amu/s.

### Chemical Analysis - Trace Metals

Whole clams, 5 or 6 per station, were thawed, and the whole body removed from the shells. Each individual clam was weighed in Pyrex beakers and dried for 16-20 h at  $105^{\circ}\text{C}$ . Twenty mL of 70% trace metal grade nitric acid were added to each beaker, which was covered with a Pyrex watch glass and heated ( $70^{\circ}$ - $75^{\circ}\text{C}$ ) on a ceramic hot plate until dry. After cooling to room temperature, another 20 mL of concentrated nitric acid were added and the dissolution continued. After 3 or 4 repeated acid additions and evaporations, 10 mL of 30% hydrogen peroxide were added, the solutions evaporated to near dryness and removed from the heat. When cooled, samples were filtered through Whatman #4 filter paper and brought to a final volume of 25 mL in a Pyrex glass-stoppered graduated cylinder by adding 5% (w/v) nitric acid. Analysis was performed on a Perkin Elmer model 5000 atomic absorption (AA) spectrophotometer employing an air-acetylene flame and conven-

<sup>4</sup>Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

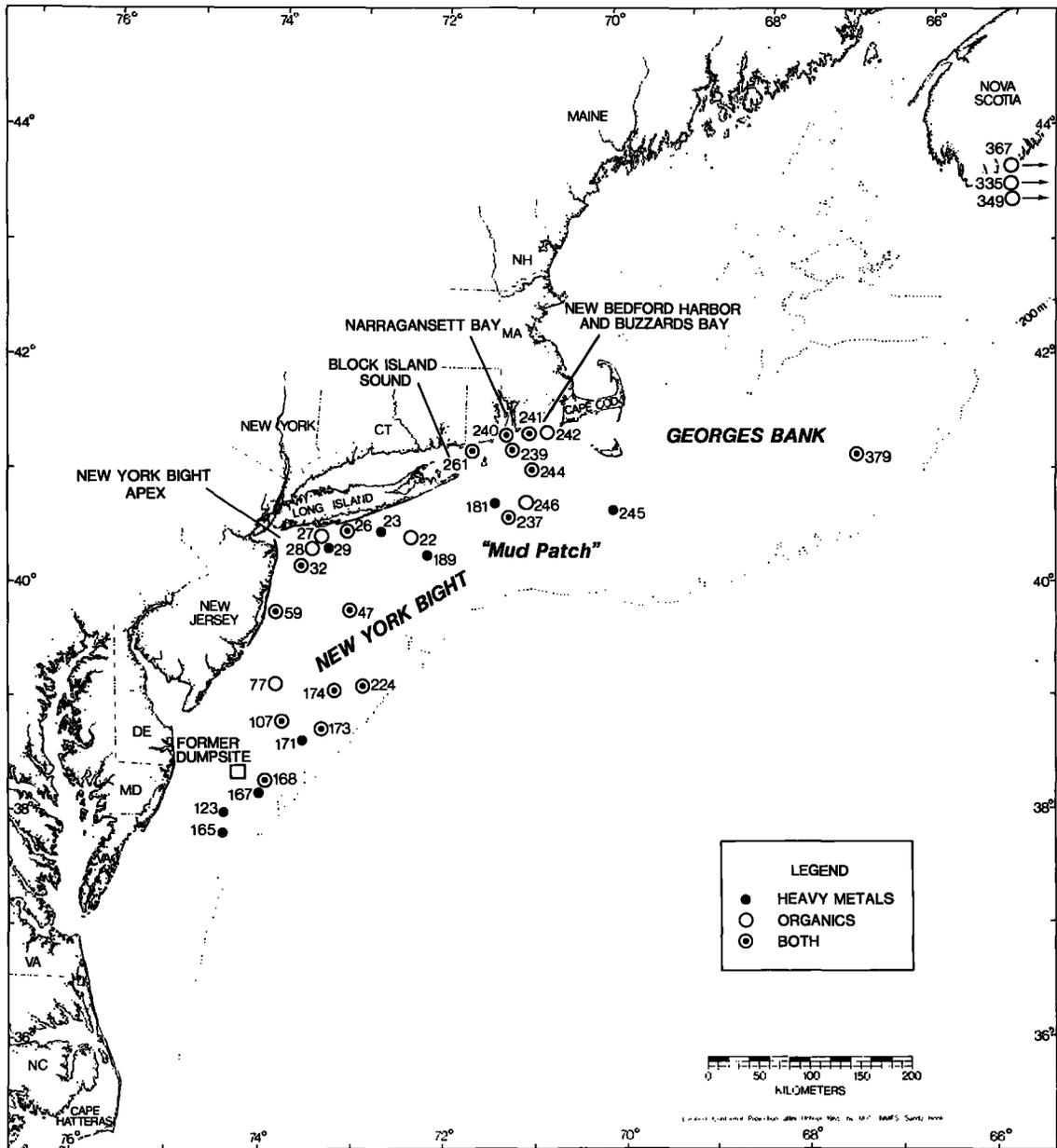


FIGURE 1.—Station locations' collections of *Aretia islandica*. Stations 367, 335 and 349 are on the Scotian Shelf at the following coordinates: Station 367 (lat. 43°44'N, long. 61°08'W), Station 335 (43°25'N, 61°42'W) and Station 349 (43°21'N, 61°23'W).

tional AA techniques. Reagent blanks were carried through the same procedure. All reagents used were of trace metal analytical grade. Deionized water was of 18 megohm purity. The National Bureau of Standards (NBS) SRM 1566, freeze-dried oyster homogenate, was used as the tissue standard. Recoveries were at least 80% of this standard in all cases.

## RESULTS

The analytical results for organic contaminants are presented in Tables 1 (PHC and PCB) and 2 (PAH). PHC values are given as total saturated and aromatic hydrocarbons as determined by GC<sup>2</sup>. PCB values are given as total tri-, tetra-, penta-, hexa-, and hepta-

TABLE 1.—PHC (petroleum hydrocarbon) and PCB (polychlorinated biphenyl) levels in northwestern Atlantic *Arctica islandica*.

Area and station	PHC ( $\mu\text{g/g}$ wet weight)			PCB (ng/g wet weight)					
	Saturated	Aromatic	Total	Cl <sub>3</sub>	Cl <sub>4</sub>	Cl <sub>5</sub>	Cl <sub>6</sub>	Cl <sub>7</sub>	Total
Inshore New York Bight									
22	0.2	1.3	1.5	4.8	5.1	1.6	4.4	0.2	16.1
26	6.0	0.9	6.9	0.4	0.3	0.2	0.5	0.1	1.5
27	0.4	0.8	1.2	7.2	2.8	1.6	1.8	<0.1	13.4
28	0.2	0.9	1.1	6.7	4.2	2.6	6.5	0.1	20.2
32	3.2	4.1	7.3	5.4	5.1	4.1	10.7	0.7	26.8
47	<0.1	0.2	0.2	1.1	0.4	0.1	0.3	—	1.9
59	3.1	1.5	4.6	3.4	3.6	3.0	5.7	0.5	16.4
Offshore NJ-VA									
77	1.7	0.7	2.4	5.6	1.2	2.9	2.3	0.3	12.2
107	0.2	0.8	1.0	8.0	1.7	0.8	2.8	0.2	13.3
168	0.2	1.1	1.3	2.3	1.3	1.0	3.5	0.5	8.5
173	0.4	0.5	0.9	4.4	4.5	1.3	3.4	—	14.0
174	1.0	0.3	1.3	2.6	0.8	0.4	1.5	<0.1	5.5
224	1.7	0.2	1.9	2.3	1.5	0.5	0.5	<0.1	4.9
Inshore S. New England									
237	0.1	0.8	0.9	1.0	0.6	<0.1	<0.1	—	1.7
246	1.2	0.4	1.6	2.0	2.8	2.2	1.5	—	8.5
244	2.2	1.3	3.5	4.9	9.5	2.3	3.8	—	20.4
261	2.0	0.4	2.4	3.4	3.5	2.1	3.1	<0.1	12.1
239	2.9	1.1	4.0	1.4	2.1	1.6	1.9	<0.1	7.0
240	2.8	0.9	3.7	2.2	2.6	2.7	3.5	<0.1	11.0
241	2.3	1.6	3.9	4.1	6.6	6.2	6.3	0.2	23.2
242	1.9	1.8	3.7	2.9	4.6	5.9	6.5	0.2	20.1
Georges Bank									
379	0.8	1.1	1.9	0.7	1.2	0.9	1.0	<0.1	3.8
Scotian Shelf									
367	0.6	0.2	0.8	0.8	0.5	0.4	0.3	0.3	2.2
335	1.1	0.1	1.2	0.9	0.4	0.5	2.3	0.1	4.2
349	4.5	0.6	5.1	0.8	0.9	0.4	0.1	—	2.2

chlorobiphenyls (Cl<sub>3</sub>-Cl<sub>7</sub>), as well as total PCB. PAH values are presented as individual compounds (e.g., naphthalene) or as homologous series ( $\Sigma\text{N}$ ). Table 3 lists the mean trace metal concentrations and standard deviations; data are presented on a dry weight basis to simplify comparisons with other studies.

## DISCUSSION

PCB levels observed in this survey ranged from 2 to 30 ng/g (ppb) wet weight (Table 1). These values are in general agreement with other data reported for PCB levels in other coastal bivalves (Giam et al. 1976; Goldberg 1978; Gadbois 1982), but are lower than those (to 400 ppb) reported for estuarine species (Goldberg 1978; MacLeod et al. 1981; O'Connor et al. 1982; ERCO 1983). However, we have found little data on PCB levels in offshore molluscs nor any other data on PCB levels in *A. islandica* for comparison. None of the *A. islandica* levels approach the current 2 ppm (= 2,000 ppb) U.S. Food and Drug Administration (FDA) "seafood action limit" for human consumption.

In spite of the wide geographical range sampled, PCB levels were relatively uniform with only an

order of magnitude difference between the high and low values. Clearly the Georges Bank (station 379) and remote Nova Scotia (stations 367, 335, 349) ocean quahogs were minimally contaminated, with their levels (2-5 ppb) reflecting the global PCB transport phenomena. The ocean quahogs in the nearshore New York Bight, Rhode Island Sound, and Buzzards Bay were more contaminated, with values up to 25 ppb. It is not surprising as previous biogeochemical studies in the western North Atlantic have clearly shown that several major urban pollutant sources influence the nearshore environment. For example, inputs of PCBs are specifically known to occur in the New York Bight, from estuarine fluxes and via direct ocean dumping (Boehm 1983b) and in Buzzards Bay, MA, from industrial inputs to the New Bedford Harbor region (Weaver 1982). Somewhat surprising were the elevated levels at some stations on the outer New Jersey shelf (12-16 ppb) and in the Hudson Canyon area (20 ppb). Offshore transport of PCB material towards these stations via riverine fluxes followed by southerly transport along the New Jersey shore and down-canyon transport of ocean-dumped material are possible modes of transport to these stations (Boehm 1983b).

TABLE 2.—PAH (polynuclear aromatic hydrocarbon) levels in northwestern Atlantic *Arctica islandica* (ng/g wet weight).

Area and station	N	ΣN	P	ΣP	ΣDBT	ΣF	Σ202	Σ228	Σ252	B(a)P	ΣPAH	PPI <sup>1</sup>
Inshore New York Bight												
22	nd	nd	4.0	11.9	2.0	1.2	5.5	1.1	<1	<1	23	40
26	nd	nd	1.1	1.1	nd	nd	1.1	nd	nd	nd	3.3	0
27	1.0	4.5	2.1	9.1	2.7	1.2	2.7	<1	<1	nd	22	54
28	9.1	12.0	1.3	5.2	<1	nd	1.8	nd	nd	nd	20	72
32	nd	nd	3.9	12.4	nd	nd	11.1	14.1	17.3	6.0	55	7
47	4.3	5.1	2.9	2.9	nd	nd	3.1	3.0	4.0	2.0	18	28
59	1.0	5.3	1.0	11.5	<1	nd	1.5	<1	nd	nd	20	77
Offshore NJ-VA												
77	<1	3.7	3.3	9.2	<1	1.0	2.4	<1	nd	nd	18	65
107	<1	6.7	2.5	10.0	2.5	3.5	1.5	<1	<1	nd	26	77
168	nd	nd	1.8	1.8	nd	nd	2.4	nd	nd	nd	4.2	0
173	1.3	5.9	1.8	6.2	1.3	2.0	2.3	<1	nd	nd	19	72
174	<1	4.0	1.0	5.0	<1	nd	4.0	1.0	1.0	nd	16	56
224	1.4	6.1	2.0	7.8	2.1	1.5	1.3	<1	<1	<1	21	74
Mud Patch												
237	<1	<1	2.8	5.0	<1	nd	5.7	3.7	5.4	2.5	19	31
246	nd	11.9	2.2	11.5	1.0	1.3	3.3	nd	nd	nd	29	81
Inshore S. New England												
244	nd	nd	nd	nd	2.4	nd	1.7	<1	<1	<1	6.1	39
261	nd	nd	3.6	9.2	<1	<1	3.3	nd	nd	nd	15	51
239	nd	nd	1.6	1.9	nd	nd	2.9	<1	1.2	<1	7.0	4
240	<1	3.3	1.8	5.6	<1	<1	2.8	<1	<1	<1	16	51
241	nd	nd	nd	5.0	nd	nd	4.0	1.0	1.0	<1	12	42
242	nd	nd	<1	<1	nd	nd	1.5	nd	nd	nd	2.5	40
Georges Bank												
379	nd	nd	<1	<1	nd	nd	<1	nd	nd	nd	<1	0
Scotian Shelf												
367	1.0	1.0	1.5	1.5	nd	nd	1.1	nd	nd	nd	3.6	28
335	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0
349	4.3	5.1	2.9	2.9	nd	nd	3.1	3.0	4.0	2.0	18	28

Wet weight concentrations = dry weight concentration ÷ 7.

N = naphthalene.

ΣN = total naphthalenes (C<sub>10</sub>-C<sub>12</sub>).

P = phenanthrene.

ΣP = total phenanthrenes (C<sub>12</sub>-C<sub>14</sub>).ΣDBT = total dibenzothiophenes (C<sub>10</sub>-C<sub>13</sub>).ΣF = total fluorenes (C<sub>12</sub>-C<sub>13</sub>).

Σ202 = fluoranthene + pyrene.

Σ228 = benzantracene + chrysene.

Σ252 = benzofluoranthenes + benzopyrenes.

B(a)P = benzo(a)pyrene.

nd = not detected (&lt;1 ng/g wet weight).

PPI = percent petroleum index =  $\frac{\Sigma N + \Sigma DBT + (\Sigma P - P) + \Sigma F}{\Sigma PAH}$ 

ΣPAH = ΣN + ΣP + ΣDBT + ΣF + Σ202 + Σ252 + Σ228

<sup>1</sup>From Boehm (1983a).

Trends in the PHC and PAH data reveal large-scale homogeneity in the concentrations observed. PAH levels ranged from nondetectable to 55 ppb, the highest values occurring at the station 32 samples from the New York Bight, where the highest PCB level (27 ppb) was also observed. Although our sampling on Georges Bank consisted of only one station, results were similar to those of a more extensive study by Payne et al. (1982), the only other study of *A. islandica* we could locate that includes PHC data. If the entire Northeast region is considered a sample set, then the PAH values were  $16.7 \pm 12.0$ . However, the composition of the PAH which com-

prises the total PAH number varied considerably, ranging from 0 to 81% "petroleum" PAH (Table 2). The percent petroleum index (PPI), developed by Boehm (1983a, b), estimates the relative contributions of uncombusted fossil fuels, e.g., petroleum, and from combustion sources to the total PAH assemblage. This indice, presented in Table 2, is based on the relative abundance of petroleum constituents, such as naphthalene, fluorenes, dibenzothiophenes, and alkylated phenanthrenes, to the total PAH mix. The differences in PPI values for the various samples cannot, at this time, be ascribed to specific transport or selective uptake factors. However, a knowl-

TABLE 3.—*Arctica islandica* trace metal body burdens (mean and standard deviation,  $\mu\text{g/g}$ -dry weight) in areas of the northwest Atlantic; N = number of individual clams examined at each site. Results of analysis of SRM 1566 are also included; 5-8 NBS (National Bureau of Standards) samples were examined for each metal (nd = nondetectable).

Area and station	N	Ag		Cd		Cr		Cu		Ni		Pb		Zn	
		X	$\pm$ SD	X	$\pm$ SD	X	$\pm$ SD	X	$\pm$ SD	X	$\pm$ SD	X	$\pm$ SD	X	$\pm$ SD
<b>Georges Bank</b>															
379	6	0.79	0.25	1.36	0.33	3.07	1.38	10.30	2.22	3.46	1.17	4.08	2.07	61.8	11.4
<b>Nantucket</b>															
245	5	0.96	0.09	2.75	0.66	2.98	0.83	7.25	1.41	9.54	3.81	5.02	2.21	88.3	21.3
<b>S. New England</b>															
237	6	2.65	2.08	3.22	0.65	2.72	0.65	12.76	3.30	27.19	8.18	6.90	1.87	153.9	87.6
181	6	1.14	0.95	3.49	1.39	2.24	0.23	11.70	2.97	21.84	7.22	11.03	4.48	124.7	30.8
244	6	0.56	0.14	1.36	0.47	2.19	1.02	6.49	3.29	4.47	1.75	2.99	1.33	84.1	25.7
<b>Rhode Island Sound</b>															
239	6	0.79	0.25	1.36	0.33	3.07	1.38	10.30	2.22	3.46	1.17	4.08	2.07	61.8	11.4
240	6	1.76	0.65	1.39	0.48	4.02	1.26	11.47	2.92	6.28	1.61	6.71	2.51	87.4	12.8
241	6	1.59	0.93	0.96	0.14	3.96	2.23	12.47	3.80	5.83	2.42	4.61	1.71	126.3	55.4
<b>Block Island Sound</b>															
261	6	1.53	1.82	1.94	0.68	4.56	0.33	10.22	1.55	11.64	3.28	10.17	2.48	101.9	32.6
<b>S. Long Island</b>															
189	6	0.74	0.60	2.48	0.83	1.88	0.59	8.78	0.94	18.73	4.75	3.30	0.80	128.4	35.2
23	6	1.18	0.53	2.17	0.67	1.09	0.19	10.31	3.27	17.28	6.07	3.41	1.12	120.2	19.6
26	6	0.84	0.45	1.43	0.56	5.47	1.22	15.78	5.83	9.87	2.73	8.66	3.25	117.6	35.7
29	6	5.25	1.64	1.06	0.29	4.78	3.35	13.65	3.20	8.93	5.06	9.67	4.11	100.7	49.9
<b>New Jersey Shelf</b>															
32	6	0.52	0.26	0.67	0.35	2.38	0.20	8.16	5.38	4.47	2.90	3.46	2.24	50.2	22.0
47	5	0.53	0.36	1.20	0.42	1.46	0.83	8.37	2.49	9.87	5.09	3.11	0.87	84.1	31.8
59	3	0.44	0.15	0.23	0.05	0.90	0.09	6.01	1.37	6.01	1.68	1.64	0.28	62.2	18.8
174	6	1.50	0.91	2.19	0.93	1.87	0.65	4.08	0.82	7.79	2.70	4.16	1.60	50.8	6.0
224	6	0.46	0.13	3.06	0.91	1.78	0.43	5.63	1.02	14.91	6.92	5.60	2.23	91.9	33.9
<b>Delmarva Shelf</b>															
107	6	0.39	0.25	1.87	0.62	2.44	0.90	4.16	1.02	10.27	2.52	4.80	2.77	58.9	14.2
173	5	0.44	0.30	2.34	1.54	1.62	0.48	4.46	1.76	11.14	4.94	4.35	2.32	61.4	26.2
171	6	0.51	0.12	1.66	0.56	1.71	0.44	5.25	1.57	10.91	3.21	3.55	1.09	75.8	31.8
167	6	0.52	0.29	1.59	0.48	1.98	0.56	7.04	4.36	9.45	4.20	3.54	1.21	76.2	43.4
168	5	2.22	1.36	3.08	1.03	2.38	0.68	5.19	1.79	13.74	5.34	6.51	2.57	74.6	14.8
123	6	2.40	1.68	2.53	0.58	3.34	1.01	4.98	1.16	14.13	3.95	5.91	1.58	77.9	20.6
165	5	0.54	0.36	2.09	0.68	2.36	0.78	6.44	2.39	11.48	4.78	4.35	2.21	74.4	28.5
<b>NBS SRM 1566</b>															
—	8	0.71	0.24	2.86	0.19	1.07	0.52	49.50	4.00	1.72	0.35	nd	—	772.0	53.0

edge of a baseline PPI value can be important for discerning the source of any change in contaminant levels in benthic animals.

In a similar manner, the PCB value has been separated, by virtue of the use of capillary GC, into isometric groupings (Table 1). Again, there were differences in PCB composition between samples. For example, samples from stations 22, 28, 32, and 244 were largely comprised of tri-, tetra-, and hexachloro PCB isomers, while those from stations 107 and 27 contained significantly greater quantities of the trichlorobiphenyls. Aroclor 1016 and 1242 contain proportionately more of the  $\text{Cl}_1$  to  $\text{Cl}_4$  isomers while Aroclor 1254 contains a greater abundance of  $\text{Cl}_4$  to  $\text{Cl}_6$  isomers. In the future, it may be possible to ascribe the differences in the PCB composition in animals to possible sources through capillary GC/ECD measurements.

Highest trace metal concentrations in *A. islandica* varied from metal to metal (Table 3); however, high-

est mean Ag, Cr, Cu, and Pb concentrations were found in New York Bight (stations 26 and 29), while Ni and Zn were highest in the "Mud Patch" (stations 181 and 237) with the highest Cd values off Delaware (Table 3). Lowest concentrations, overall, were observed at midshelf stations off New Jersey and Maryland (with the exception of stations 167, 168, and 123 that could have been influenced by dumping at a nearby dumpsite) and station 379, on Georges Bank. Comparison of these data with those of Wenzloff et al. (1979), who analyzed metals in ocean quahogs from the New York Bight to an area off Chesapeake Bay, was attempted for temporal trends. Unfortunately, the Wenzloff et al. (1979) data were obtained from only foot muscle composites of 5 or 6 quahogs at each station, reported as means of all composites per half degree of latitude; hence, a direct comparison was not possible. The geographic pattern, a decrease in metal concentrations with latitude believed present in the Middle Atlantic Bight

by Wenzloff et al. (1979), was not apparent from the present data or from the studies summarized in Table 4. Results of other studies involving whole body analysis (Table 4) suggest that Cd, Ni, and Zn could also be high on Georges Bank; otherwise, the values presented do not support any consistent latitudinal trends.

Results indicate, however, on a local level, elevated trace metal levels were also usually associated with known areas of inputs, e.g., waste dumpsites or adjacent to heavily industrialized coastal areas, such as the New York Bight apex (station 29), or natural depositional areas where trace metals from unknown sources are apparently accumulating, e.g., the "Mud Patch" (stations 181, 237).

The uptake and accumulation of trace metals by marine organisms are known to be affected by a number of variables. These variables include season, age, size, temperature, and interactive effects of several metals (Phillips 1977), and can be sources of some of the variability shown between the results of studies in the same area. Methodology is another source of variability between the results of each study, especially when intercalibrated results with standards are not available. It is interesting to note that an expected close correlation between trace metal levels in the sediment and in *A. islandica* tissues was not evident in at least one study (Reynolds 1979), suggesting that the water and food or

other suspended material could be the primary source of contaminants to this filter-feeding species.

In conclusion, a set of measurements of several organic and seven trace metal contaminant levels in the commercially valuable ocean quahog have been obtained from a wide range of northwestern Atlantic locations. This set can be used as a base to monitor long-term changes in the assimilated levels and distributions of these compounds in this species and the risk to its health of future use as food. The levels found were well below the FDA seafood action limit, but elevated values were associated with impacted coastal habitats and possibly waste dumpsites.

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TABLE 4.—Comparison of mean trace metals levels ( $\mu\text{g g}^{-1}$  dry wt.) in *Arctica islandica* of the northwest Atlantic.

Area and reference	Ag	Cd	Cr	Cu	Ni	Pb	Zn	Tissue type
Georges Bank-Nantucket								
Sick (1978)	0.1	1.1	0.9	3.5	12.4	0.35	252	Whole body
Erco (1978)		5.1	3.9	7.6	21.0	1.00	260	Whole body
Payne et al. (1982)		4.5	1.7	5.4	27.0	3.50	150	Whole body
Present study - stn. 379	0.8	1.4	3.1	10.3	3.5	4.1	62	Whole body
Block Island Sound								
Steimle et al. (1976)		1.8		31	18.0	18.0	183	Whole body
Rogerson and Galloway (1979) <sup>1</sup>		1.4	8.1	23	11.8	10.2	138	Whole body
Present study - stn. 261		1.9	4.6	10	11.6	10.2	102	Whole body
Southern Long Island								
Guarimo et al. (1979) <sup>1</sup>		3.0	5.6	17.4	27.9	14.1	122	?
Present study - stn. 189		2.5	1.9	8.8	18.7	3.3	128	Whole body
New York Bight								
Wenzloff et al. (1979) <sup>1</sup>	15.8	3.5	<7.5	43.2	<5.0	9.8	107	Foot muscle
Sick (1981)	0.7	7.9		5.3				"muscle"
Present study - stn. 23, 26, 29, 32, 47	1.7	1.3	3.0	11.3	10.1	5.7	95	Whole body
Off Delaware								
Reynolds (1979)		2.4		7.7	9.0			Whole body
Present study - stn. 123, 167, 168		2.4		5.7	12.4			Whole body
Chesapeake Bight								
Wenzloff et al. (1979) <sup>1</sup>	9.3	3.3	<8.0	34.6	<4.7	8.5	98	Foot muscle
Present study - stn. 107 and south	1.0	2.2	2.3	5.4	11.6	4.7	71	Whole body

<sup>1</sup>Original wet weight data converted into dry weight by multiplying by 8.

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